One-way FSI simulation of a wire-wrapped fuel rod

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In the development of novel nuclear technologies, many design decisions are revisited and drastically different choices than in the past are considered, resulting in new challenges and knowledge gaps to be bridged. The MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications) is a prototype of an accelerator-driven fast reactor, using Lead-bismuth Eutectic (LBE) as coolant and fuel assemblies in hexagonal arrays with a wire wrapped helicoidally around the pins to maintain spacing. One of the challenges that arises is possible flow-induced vibrations (FIV): as LBE is more than 10 times as dense as water the rods are subjected to larger flow forces and the wire-wrap might alter the vibration characteristics.

The type of FIV that is mainly of interest is turbulent buffeting, vibrations related to the fluctuating pressure field associated with the turbulent flow. In order to resolve the turbulent flow, large eddy simulation (LES) or direct numerical simulation (DNS) is required, imposing a high computational demand. Using such model in a two-way coupled fluid-structure interaction (FSI) simulation is computationally expensive, therefore a different approach was followed, attempting to investigate the vibrational behavior of a wire-wrapped fuel bundle in a computationally affordable way by capturing all relevant physics by the dedicated, applicable models and combining the results in a one-way FSI simulation.

In a first step, experimental work was performed, investigating the vibrations of both a bare and a wire-wrapped fuel pin in air. The results were used to create a model of 7-pin bare bundle, with the effect of the wire lumped into the bare pins by adjusting its modal properties. A two-way coupled FSI simulation on this 7-rod bundle resulted in the bundle eigenfrequencies and damping ratios in the presence of LBE. The third step consisted of an LES (performed by ANL) on a 19-pin bundle, yielding the pressure field acting on the rods. This pressure field is used in the final step, where they are applied to a structural model of a wire-wrapped pin, with the modal properties tuned to match the bundle modal properties of the FSI step. This structural model uses contact detection to implement the presence of the neighboring rods.